

Principal component analysis applied to biomonitoring studies: a case study

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Abstract: Principal component analysis (PCA) was applied to test differences among metal concentrations in organisms collected in five coastal sites in a reference ecosystem that is Linosa island (Sicily, Italy). Thus, *Monodonta turbinata* B. and *Patella caerulea* L. were tested as biomonitors of trace metal contamination in marine coastal areas. The aim of this survey was to evaluate the concentrations of Cd, Cr, Cu, Pb and Zn present in soft tissues of the selected species. PCA results confirmed that most significant elements in determining the pollutant distribution were $\text{Cu} > \text{Cr} > \text{Cd} \approx \text{Zn} > \text{Pb}$. The pollutant distribution is related more significantly to species than to sites. Results confirmed the suitability of these species for biomonitoring purposes and PCA as a reliable tool for biomonitoring studies.

Keywords: Principal component analysis, biomonitoring, trace metals

1. Introduction

The goal of the present study was to gain more information on the use of the selected species as possible cosmopolitan biomonitors of trace metals present in the sea ecosystem of Linosa island by using principal component analysis (PCA) technique. Gastropod molluscs *Monodonta turbinata* and *Patella caerulea* were selected because of their demonstrated good ability as biomonitors (Campanella et al., 2001). It is worth noting that these herbivorous gastropods generally take metals mainly from the diet and *P. caerulea* is a popular food in Mediterranean areas.

Linosa island is situated in the Sicilian channel. It is 167 km far away from Sicily and 165km from the African continent. Linosa is big 5.4 Km². In order to preserve the wealth of marine flora and fauna, the Ministerial Decree 21/10/2002 decreed the creation of the Protected Sea Area of Linosa. The selected sampling stations were the following: 1) Calarena, 2) Mannarazza, 3) Pozzolana di Levante, 4) Pozzolana di Ponente 5) Faraglioni.

Individuals of *Monodonta* and *Patella* have been picked in the tidal zone, in varying number. Mineralization was carried out using a microwave oven MDS-2100-CEM. Metal concentrations in molluscs were measured using Perkin Elmer AAnalyst 300 atomic absorption spectrometer with flame atomization (FAAS) and graphite furnace system (GFAAS) with HGA 800 autosampler. For Cu and Zn, flame atomization was employed, while for Cd, Cr and Pb GFAAS was used. The accuracy of the mineralization procedures was controlled by using a certified reference material: ERM

CE 278 (mussel tissue) (Conti et al., 2006) Principal Component Analysis (PCA) was performed on standardised matrix of metal data coming from Linosa Island by means of the Statistica software (StatSoft ,OK, USA) version 5 for Windows environment.

2. Results

Table 1 shows mean metal concentrations obtained by the analyses of the molluscs.

Table 1: Concentrations of metals ($\mu\text{g g}^{-1}$ d.w.) in the soft tissues of *P.caerulea* and *M. turbinata* (means $\pm$ SD).

Sampling station	Ind.	Cd	Cr	Cu	Pb	Zn
<i>Patella caerulea</i>						
1	8	3.25 $\pm$ 0.86	0.27 $\pm$ 0.08	2.78 $\pm$ 0.88	0.40 $\pm$ 0.11	41.78 $\pm$ 10.13
2	8	3.68 $\pm$ 1.01	0.24 $\pm$ 0.10	6.22 $\pm$ 1.61	0.47 $\pm$ 0.15	38.40 $\pm$ 6.26
3	8	3.26 $\pm$ 0.97	0.75 $\pm$ 0.22	4.04 $\pm$ 1.35	1.28 $\pm$ 0.31	41.47 $\pm$ 6.87
4	8	2.69 $\pm$ 0.63	0.72 $\pm$ 0.21	9.71 $\pm$ 2.25	2.41 $\pm$ 0.65	42.84 $\pm$ 4.44
5	8	4.97 $\pm$ 1.31	0.13 $\pm$ 0.04	6.60 $\pm$ 1.14	0.51 $\pm$ 0.09	51.47 $\pm$ 9.62
<i>Monodonta turbinata</i>						
1	8	0.77 $\pm$ 0.23	0.45 $\pm$ 0.10	10.13 $\pm$ 2.81	1.66 $\pm$ 0.63	50.21 $\pm$ 2.27
2	8	1.17 $\pm$ 0.28	0.38 $\pm$ 0.08	15.31 $\pm$ 3.82	0.71 $\pm$ 0.22	50.47 $\pm$ 6.23
3	8	1.11 $\pm$ 0.20	1.30 $\pm$ 0.38	34.89 $\pm$ 9.78	1.07 $\pm$ 0.25	60.90 $\pm$ 8.63
4	8	1.11 $\pm$ 0.32	0.94 $\pm$ 0.28	28.26 $\pm$ 4.90	1.78 $\pm$ 0.49	59.29 $\pm$ 4.89
5	8	1.28 $\pm$ 0.35	0.15 $\pm$ 0.04	12.30 $\pm$ 2.37	0.62 $\pm$ 0.13	56.26 $\pm$ 8.10

In *P. caerulea* metal concentrations, decreased in the following order: Zn > Cu > Cd > Pb > Cr. *Monodonta* metal concentrations decreased in the following order: Zn > Cu > Pb > Cd > Cr.

To assess the existence of significant differences in the metal concentrations in molluscs, use of multivariate analysis (principal component analysis, PCA) was taken into account. PCA is a statistic technique belonging to the so called “unsupervised pattern recognition methods”, helpful for performing exploratory data analysis when there is no one preliminary knowledge about the characteristics (i.e. distribution and structure) of the data to be analysed (Conti, 2008, Conti et al., 2006).

The application of PCA showed that three components were able to explain the 85.84 % of total variance (figure 1). In the first factor accounting the highest fraction of variance (52.62 %) the most significant metals were Cu and Cr which had the highest loading values, 0.90 and 0.80 respectively (see below table 2). Cd and Zn showed also significant loading values (-0.69 and 0.66). In the second factor accounting a lower fraction of total variance (20.00%), only Pb showed a significant loading (0.76). So this result shows that most significant elements in determining the pollutant distribution are Cu> Cr>Cd $\approx$ Zn > Pb.

The scoreplots allowed to see how the pollutant distribution is related more significantly to species than to sites. In the scoreplot of figure 1 where the data were reported according to the living organism it is evident a marked separation between the accumulation patterns of data of the two molluscs species.

Figure 1: 3D plot of PCA applied to data from Linosa. “m” is *Monodonta*, “p” is *Patella*. The plot explains the 85.82% of total variance.

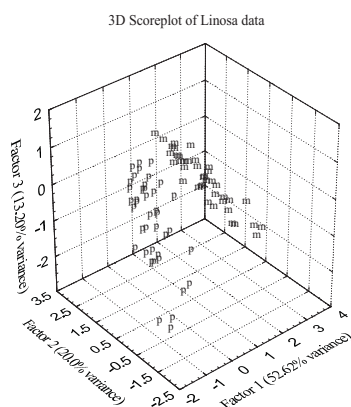
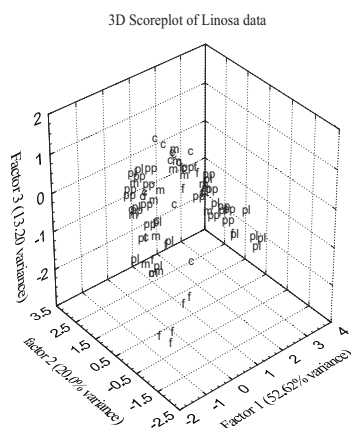


Figure 2: 3D plot of PCA applied to Linosa data. “c” Calarena, “m” Manarazza, “pl” Pozzolana di Levante, “pp” Pozzolana di Ponente, “f” Faraglioni



Above all the data for *Monodonta* are placed in the plot portion with the highest value of the first factor, it means that they have the highest accumulation of all the pollutants with Cu and Cr in particular. In the same scoreplot reported this time according to the different sites (figure 2) the data are placed without a marked separations and many sites are present overlapped with other sites. Faraglioni site only is placed well separated from the other sites, but this separations always depends on the species (i.e. *Patella*) as for the *Monodonta*. This results seem to confirm that there is no significant differences between sites and is no one site more contaminated than another. This finding agrees with the hypothesis as Linosa island as a possible reference ecosystem.

At last, the correlation matrix (table 3) showed some correlations (at 95% of statistical significance). Cu is correlated to Zn and Cu showing a probable common origin whereas Pb and Cd do not show correlation with the other elements.

Table 2: loadings obtained by PCA.

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
Cu	0.900581	-0.216787	-0.081273	0.159400
Zn	0.662907	-0.561107	-0.223015	-0.419942
Cd	-0.692997	0.016577	-0.715285	-0.009693
Pb	0.0506059	0.761798	-0.079567	-0.392309
Cr	0.802631	0.240670	-0.292031	0.406967
Expl. Var.	52.62%	20.00%	13.19%	0.104276

Table 3: correlation matrix of trace metals. Significant correlation values are reported in bold.

	Cu	Zn	Cd	Pb
Cu				
Zn	0.623377			
Cd	-0.54191	-0.31744		
Pb	0.253669	0.082427	-0.27227	
Cr	0.687412	0.321612	-0.36637	0.440593

3. Conclusions

The use of two gastropods turned out to be very valuable for the study of a coastal area with a low levels of contamination. The two species studied can be considered as a potential biomonitors of trace metal pollution. Statistical multivariate analysis (PCA) revealed two clearly separated patterns of bioaccumulation for the studied species respectively. Statistical results confirmed that most significant elements in determining the pollutant distribution were Cu> Cr>Cd ≈ Zn > Pb.

Above all, the data for *Monodonta* are placed in the plot portion (PCA) with the highest value of the first factor, it means that it has the higher levels of accumulation of pollutants with particularly high levels of Cu and Cr. Cu showed good correlation with Zn and Cd. These finding can be attributed an a probable common origin whereas Pb and Cd do not showed correlation with the other studied trace metals.

References

- Campanella L., Conti M.E., Cubadda F., Sucapane C. (2001) Trace metals in seagrass, algae and molluscs from an uncontaminated area in the Mediterranean. *Environmental Pollution*, 111, 117-126.
- Conti M. E. (Ed.) (2008), *Biological monitoring: theory and applications*. The Sustainable World, 17, pp. 228. WIT press, Southampton, ISSN: 1746-9581.
- Conti M. E., Iacobucci M., Mecozzi M., Cecchetti G. (2006) Trace metals in soft tissues of two marine gastropod molluscs: *Monodonta turbinata* B. and *Patella caerulea* L. collected in a marine reference ecosystem, in: *Environmental problems in coastal regions VI*, C.A. Brebbia, (Ed.), WIT Transactions on Ecology and the Environment 88, 3-11.